Chapter

5

LIVABLE COMMUNITIES HANDBOOK

Land Use and Design Strategies for the South Bay Cities

Transportation and Environmental Benefits

One of the primary benefits of livable communities strategies is that they can reduce automobile use and protect natural resources. This chapter describes the transportation and environmental benefits of livable communities. There are many other benefits of livable communities as well, as described in previous chapters. For example:

- Livable communities have healthier economies. A healthier commercial sector provides a city with higher sales tax revenues. A healthier residential sector benefits homeowners by raising property values.
- Livable communities are safer places. Pedestrians and bicyclists benefit from greater safety when streets are designed to reduce conflicts with automobiles. Residents and visitors are safer from crime when commercial areas are economically healthy, well lit, and populated throughout the day and evening.
- Livable communities are healthier places. When walking and biking are viable transportation alternatives, children and adults can better incorporate exercise into their daily activities. Public health professionals have recently identified single-use, auto-dominated communities as one contributor to the epidemic proportions of obesity in this country (Koplan and Dietz, 1999).

5.1 Transportation Benefits

One of the principle benefits of livable communities is a reduction in automobile use. By bringing homes, workplaces, shopping and other destinations in closer proximity, and by designing for alternative travel modes, livable communities strategies can reduce the number of automobile trips. Livable communities can also lead to shorter auto trips, thereby reducing vehicle miles of travel as well as the number of trips.

This section focuses on how livable communities can benefit the transportation system by reducing both automobile trips and miles of travel. A related benefit is a reduction in the need for parking. Reduced parking demand can benefit developers by reducing their costs if cities lower the required number of parking spaces for appropriately designed projects and allow greater flexibility in site design. It can also improve urban design and pedestrian, bicycle and transit access. These benefits are covered in previous chapters and will not be dealt with here.

5.1.1 Empirical Studies Overview

Over the past 20 years, a large body of research has focused on the affects of land use and design on travel. Most of this research has been in the form of empirical "cross-sectional" studies. These types of studies compare travel characteristics across different communities at the same time, and seek to explain variations in travel in terms of the differences in land use and design. They differ from "time-series" studies which focus on changes in one community over time.

Empirical transportation studies attempt to isolate the impact of one or more land use and design factors on travel. An important element is controlling for other factors that may be changing across different communities. For example, a flawed study design might compare transit use in several communities with different residential densities and conclude that higher density leads to higher transit use. Such a comparison does not control for income – higher income households tend to own more cars and use transit less. A better study design to isolate the impact of density on transit use would compare communities that differ in density but not in income. More sophisticated studies can control for income using statistical techniques.

One limitation of cross-sectional analysis is that it cannot prove that a particular land use or design change *causes* a travel change. Say, for example, city A has greater land use mixing than city B, and its residents are observed to walk more than those in city B. If all other factors are accounted for, this would suggest that more walking is linked to land use mixing. But such an example does not prove that if city B increases land use mixing, its residents will behave like those in city A. Despite this limitation, however, most researchers agree that empirical cross-sectional studies are the best means available to assess the benefits of land use and design on transportation.

Empirical studies tend to single out four land use and design elements that may affect travel: density, land use mixing, urban design and transit access. In reality, it is often difficult to separate these elements. For example, increasing density often involves greater land use mixing, and greater mixed use is usually accompanied by pedestrian-oriented design improvements. Careful studies try to control for these elements and isolate the impact of each one. The impact of each of these four elements is discussed below. This section draws heavily on a recent literature review prepared for the U.S. EPA (Apogee/Hagler Bailly, 1998).

5.1.2 Impact of Density

A large number of studies have shown a relationship between density and travel behavior. Areas with higher residential and employment densities generally exhibit a greater share of walking, bicycling and transit trips, shorter trip lengths, and lower vehicle ownership per household. There are several reasons for this. First, higher densities tend to bring more destinations within the acceptable range for walking. Second, higher densities can support more frequent transit service, which makes this option more attractive. Finally, higher density tends to have higher land values and thus higher prices for parking, which encourages drivers to try to find alternative travel modes.

One of the best known studies in California was done by John Holtzclaw (1994). Holtzclaw examined vehicle odometer data from the Smog Check program and compared annual household vehicle travel across different communities. Table 5.1 shows the study findings for selected communities in both Southern and Northern California. The study found that communities with higher residential density clearly exhibit lower vehicle travel per household. For example, households in southern Santa Monica, southwest Beverly Hills and southern Long Beach drive 13,000 to 15,300 miles per year on average. Households in central Downey, Alhambra and Claremont drive 21,400 to 22,700 miles per year on average. In general, the study suggests that doubling residential density reduces vehicle mileage per household by 20%.

Table 5.1 Residential Density and VMT Across California Cities

Sample Community	VMT/HHold	HHold/Resid Acre
Southern California		
Southwest Beverly Hills	12,972	14
Southern Santa Monica	14,725	15
Southern Long Beach	15,252	24
Uptown San Diego	15,483	12
South Central Pasadena	17,256	10
Central Downey	21,409	7
Alhambra	21,658	9
Esdondido	21,695	4
Claremont	22,681	6
Nothern Riverside	23,690	5
La Costa	27,360	4
Morena Valley	28,721	4
Northern California		
Northeast San Francisco	5,500	101
Central Sacramento	10,100	22
Central Berkeley	12,500	16
Rockridge (Oakland)	14,300	10
Alameda	17,000	12
Daly City	19,300	15
Walnut Creek	22,300	5
Lafayette	22,300	2
Morgan Hill	28,400	2

Holtzclaw also found that in addition to higher residential density, the neighborhoods with lower vehicle miles traveled (VMT) tend to have greater land use mixing, better pedestrian access, and more frequent transit service . All of these factors likely contribute to the differences in travel behavior.

Holtzclaw's study did not control for other factors such as income or land use mix, and this makes it difficult to draw reliable conclusions about the impact of density alone. However, several other recent studies attempted to control for these factors and also suggest that high density leads to reduced vehicle ownership and use.

Professor Robert Cervero (1996) of UC Berkeley used the 1985 American Housing Survey to analyze the effects of various land use factors. His study found that vehicle ownership declines as residential density and land use mixing increase. Households in neighborhoods of mid-rise apartments tend to own 0.29 fewer vehicles than single-family detached households, even when controlling for income, number of household members, transit service and other factors. When households have commercial or other non-residential land uses nearby, they tend to own 0.1 fewer vehicles. These findings are significant because, logically, households owning fewer vehicles are consistently shown to drive less.

In addition to residential density, higher employment density has also been shown to be related to lower levels of vehicle use. In a study in the Seattle area, Frank and Pivo (1994) used a regional household transportation survey to test the impacts of land use mix, population density, and employment density on mode of travel. They found that the percent of transit use is highly correlated with employment density for both work and shopping trips. Increasing density from 20 to 75 employees per acre leads to a drop in the portion of single-occupant vehicle trips from roughly 90% to 60%.

5.1.3 Impact of Land Use Mixing

Increasing land use mix can reduce vehicle travel in a number of ways. Greater mixing will bring activity destinations closer together, allowing more trips to be accomplished by walking and bicycling. In some cases, multiple activities can be accomplished at the same site. Closer activities can also reduce the length of vehicle trips.

Land use mixing can take a variety of forms. Increasing commercial and other land uses in a residential neighborhood can reduce vehicle use to and from the home. Similarly, a greater mix of land uses at employment locations can reduce vehicle use before, during and after the work day.

Residential Neighborhood Mixing

In the Seattle area, a study by Rutherford et al (1996) compared the average daily household travel mileage across neighborhoods with different levels of land use mixing. The data were split into two income groups to control for some of the differences associated with income. In neighborhoods with high levels of mixing, daily travel mileage was generally less than half that in suburban, single-use neighborhoods. These differences applied to single adults, families with children, and seniors. The share of non-motorized trips was also much higher in the mixed-use communities. The percentage of walk trips was approximately 18% in mixed-use Seattle communities, 7.8% in mixed-use suburbs, and only 2.0% in outer suburbs.

The study described earlier by Cervero (1996) also looked at the impact of land use mixing on travel. This study found that having retail land uses in close proximity to residences is associated with a lower share of automobile commuting, controlling for income and transit service. Households with retail shopping within one to two blocks are more likely to commute to work by transit, walking or bicycling. This finding suggests that when households are forced to drive to accomplish frequent activities like grocery shopping, they may be more likely to drive to work and do their shopping on the way home. When these services are within walking distance, residents are able to commute by alternative modes.

An important study in Florida by Ewing et al (1996) suggests that even when transit and non-motorized travel options are not widely available, greater land use mixing can reduce vehicle use. The study examined travel records in suburban communities with little transit service. In communities where shopping, recreation and schools are clustered, vehicle hours of travel are significantly lower. Land use mixing allows drivers to accomplish more tasks per trip, even when alternative modes are not an option.

A study by Kockelman (1997) examines the impact of several different aspects of land use mixing on travel. These include land use balance (the degree of balance between residential, commercial, public, offices, industrial and recreational land uses), land use dissimilarity (how closely different land uses come in contact with one another), and accessibility (the number of jobs within 30 minutes of travel). The study finds that increasing any of these measures will reduce vehicle miles traveled (VMT) per household, controlling for demographic variables. The mixing variables were found to be more closely related to VMT than density measures.

Employment Center Mixing

The mixing of office employment with retail land uses can significantly reduce vehicle travel associated with trips during the work day. By offering retail and services near employment centers, workers can accomplish errands by foot . Workers are also more likely to use transit for commuting if there are shopping and eating options near the workplace.

Research has found reduced vehicle use and increased transit use at employment centers that include a mix of commercial space. This seems to hold for both auto-oriented suburban centers and more urban areas. Cervero (1988) found that at large office developments, a 10% increase in retail and commercial space is associated with a 3% increase in transit and ridesharing. In another study, Cervero (1991) found that at large suburban activity centers, the number of vehicle trips per employee was 8% lower at centers with retail space, compared to those without retail.

In a study of commuting in the Los Angeles area, Cambridge Systematics (1994) analyzed how commute mode varies with the presence of transportation demand management (TDM) and mixed land uses. The study found that when TDM is used, transit use at employment sites with mixed land uses is 3.5% higher than at other sites. If no TDM is used, transit use is 1.9% higher at mixed use sites. The portion of walking and bicycling is also higher at mixed use employment sites.

5.1.4 Impact of Urban Design

Urban design includes a variety of factors such as architecture, building height and setback, block size, street width and pedestrian facilities. Most studies have found it difficult to isolate the impact of urban design on travel. Urban design is more difficult to quantify than density or land use mix. In addition, changes in urban design usually occur in conjunction with other land use changes. For example, areas that are considered to have pedestrian-friendly urban design typically also exhibit higher levels of land use mixing and higher density. Studies need to control for these factors and others such as income in order to estimate the impact of urban design alone.

One recent study of urban design impacts was conducted by Professor Anne Vernez Moudon (1997) in the Seattle area. She compared neighborhoods that have similar population density, income, land use type and mix, and area, but differ in pedestrian environment. The study measured pedestrian activity in 12 different neighborhoods. All contain a neighborhood commercial center with roughly the same land use mix surrounded by approximately 6,000 people living within one-half square mile. Six of the neighborhoods were characterized by smaller blocks (equivalent to 300 by 400 feet on average) and a complete and continuous sidewalk system on both sides of the street. The other six were characterized by large blocks (equivalent to 1000 by 1300 feet on average) and an incomplete and discontinuous sidewalk system lining, on average, less than half the streets. At the first six sites, researchers observed roughly three times as many pedestrians per hour as at the second six sites. Thus, pedestrian activity appears to be significantly higher in neighborhoods that contain small blocks and continuous, connected sidewalks, even when controlling for other factors. This study does not directly address the affects of urban design on reducing vehicle use, however.

Another study attempted to examine the influence of site "aesthetics" on travel. The study (Cambridge Systematics, 1994) looked at employers with TDM programs and compared those sites considered more aesthetic versus less aesthetic. The aesthetics rating was based on street noise, number of signs and the quality of landscaping. Employment sites rated as more aesthetic had a percentage of transit users nearly twice that of the other sites.

A study in the San Francisco Bay Area (TCRP, 1996) compared the choice of travel modes across census tracts that differ in urban design, land use mix and density. As shown in Table 5.2, the study compared two neighborhoods with similar household incomes and demographics. The Rockridge neighborhood has a residential density three times higher than the Lafayette neighborhood, and is characterized by a greater land use mix and smaller blocks. The share of non-work trips made by transit is 2.5 times higher in Rockridge, while the share of walk/bike trips is 5 times higher. The study also examined the impact of specific urban design factors, including residential building types, sidewalk and street widths, and building setbacks. No single design factor was found to have a significant impact on travel in isolation. However, a combination of urban design factors was correlated with a 10% reduction in automobile use for non-work trips.

Table 5.2 Land Use, Design and Travel Behavior in Two Neighborhoods

Variable	Rockridge	Lafayette
Common Characteristics		
Median household income, 1989	$58,770	$61,071
Median age	37.3	39.8
Percent persons who are white	73.8	88.2
Percent adults college educated	44.5	40.7
Median housing values	$322,595	$392,853
Number of bus lines serving area	3	3
Differing Characteristics		
Housing density (units per sq mile)	2,194	655
Percent housing single-fam detached	64	78
Blocks per square mile	103	47
Average block length	80	380
Non-work Trip Travel Mode		
Percent trips by auto	85	96
Percent trips by transit	5	2
Percent trips by walk/bike	10	2

Other studies have examined how traffic levels can affect residents' perception of their neighborhood. The classic study by Appleyard (1981) compared households in the same neighborhood that differ only in the amount of traffic in their street. Residents living on streets with higher traffic volumes were found to travel less on foot, have less interaction with neighbors, and generally view their neighborhood more negatively. While these types of studies do not directly consider reduction in vehicle use, they do suggest a greater willingness to walk on streets with traffic calming.

5.1.5 Impact of Transit Access

A number of studies have examined how transit service affects travel behavior. Most of these studies examine travel in areas with comprehensive regional rail systems and thus may not be directly analogous to the South Bay. Some studies, however, have included areas served by bus transit only.

A study for the California Air Resources Board (Dagang and JHK & Associates, 1993) surveyed visitors to regional shopping centers to analyze the impact of transit service and the density and proximity of surrounding land use on travel mode. Five shopping centers were studied, as identified by the acronyms below:

- SL1: first suburban location with low surrounding land use densities and transit service
- SL2: second suburban location with low surrounding land use densities and transit service
- SM: suburban location with medium surrounding land use densities and transit service.
- SH: suburban location with high surrounding land use densities and transit service
- UH: urban location with high surrounding land use densities and transit service

The study found that better transit service and higher density surrounding a center can lead to a much lower share of trips by automobile. Table 5.3 shows the percentage of trips by travel mode for each shopping center. Importantly, these trends hold up even when controlling for demographic variables. For example, among households earning over $75,000 per year, the percentage of trips by automobile was 100% at the two low density suburban centers, 80% at SM, 67% at SH and 47% are UH. The trends are also consistent across gender, age and household size. This study is important because it shows that transit service and land use can play a big role in reducing auto use for shopping trips.

Table 5.3 Travel Mode Across Shopping Center Types

Travel Mode	SL1	SL2	SM	SH	UH
Auto	95%	91%	69%	57%	38%
Transit	4%	6%	11%	21%	33%
Bicycle	0%	1%	1%	0%	0%
Walk	1%	2%	19%	22%	29%
Total	100%	100%	100%	100%	100%

5.1.6 Taking Credit for Transportation Benefits

Since livable communities can clearly reduce automobile use, the key question is how can cities and developers take credit for this reduction. When developers raise density, increase land use mixing, or improve pedestrian and transit access, they should benefit from the reduced impact of their project on the transportation system. The current standards for reviewing traffic impacts, however, do not take into account this likely result.

Under the California Environmental Quality Act (CEQA), new development must be evaluated in terms of its environmental impacts, including transportation. An Environmental Impact Report (EIR) is prepared for projects that are determined to have significant impacts. The EIR documents the impacts and may propose mitigation measures.

Transportation impacts are usually most acute at intersections. Both signalized and unsignalized intersections can handle only a fixed number of vehicles. When a new project generates more vehicle trips through an intersection, it may increase the delay. To mitigate these impacts, developers may be forced to contribute to the cost of "improving" the intersection – adding lanes or turn pockets, adjusting or automating signal timing, or other measures that allow more vehicle throughput.

ITE Trip Generation Rates

The typical process of predicting the number of new vehicle trips associated with a new development is to use the Institute of Transportation Engineers (ITE) *Trip Generation Manual*. The *Trip Generation Manual* compiles traffic impact studies from around the country to estimate average trip generation rates for each land use. For example, rates may be developed for medium density apartments, large shopping centers, and cinemas. These rates would be expressed as the number of new trips per dwelling unit, per square foot, or per seat.

The ITE trip generation rates are based on a large number of different studies, and generally do not account for the land use and design factors that are part of livable communities. Rather, most of the studies used to develop the ITE rates are performed in single-use, lower density suburban communities with little transit service. If studies are done in higher density, mixed use and transit accessible locations, the ITE *Manual* does not distinguish them. Using the ITE trip generation rates to determine transportation impacts will therefore not allow a developer to take full credit for the transportation benefits of livable communities.

Customized Studies

One solution is to develop trip generation rates specifically for local projects that have mixed-use or pedestrian-oriented characteristics. For example, the San Diego

Association of Governments (SanDAG) produces a guide to trip generation rates for use in the San Diego region. The agency conducted a study of the Uptown District, a mixed use neighborhood built on the site of an old Sears. At the time of the study, the development contained 310 attached dwelling units, a popular Ralph's supermarket, and 74,000 square feet of other retail, restaurants and office space. Table 5.4 shows the trip generation rates developed and those that would have been applied as default values. The commercial trip rate was found to be 8% lower than the default, while the residential trip rate was 16% lower.

Table 5.4 Measured Travel Benefits of Uptown District

	Uptown District	Default Rates
Commercial Rate	110 trips/1000 sq.ft.	120 trips/1000 sq.ft.
Residential Rate	5 trips/dwelling unit	6 trips/dwelling unit

Obviously, most developers of mixed use or pedestrian/transit oriented projects would prefer to show a reduced traffic impact. A customized traffic impact study, however, requires hiring a transportation consultant, and developers of small projects may not find it cost effective to pay for showing a reduced traffic impact. Wherever possible, cities should encourage developers to rely on traffic impact studies conducted for similar projects, such as the one conducted on the Uptown District.

5.1.7 The URBEMIS Model

For larger projects, a specialized computer model can be used to show the reduced transportation and environmental impacts of livable communities strategies. This models, called URBEMIS, is used to estimate the emissions resulting from new project development as part of the CEQA environmental review process. The most recent version of the model, URBEMIS7G, was developed for the San Joaquin Valley Unified Air Pollution Control District. Other air districts in the state now allow use of the model, including the South Coast Air Quality Management District. URBEMIS7G differs from previous editions in that it can explicitly account for the travel and emissions benefits of mixed use and design factors that are supportive of pedestrian, bicycle or transit use. The portions of the model that calculate trip reduction benefits are described in greater detail below.

Accounting for Mixed Use

In a single-use development, trips for work, shopping or recreation normally require leaving the site and then returning. In mixed use development, a portion of trips will occur internally to the site. Since these trips are normally accomplished by foot, they do not contribute to traffic and air pollution emissions. If a traffic impact analysis fails to account for these internal trips, then the traffic impacts of the project are overestimated.

The portion of trips that occur internally to a mixed use project depends on the project's size, the urban context in which it is being built, and the nature of the land uses. The larger the project, and the more evenly balanced the land uses, the larger the portion of internal trips. In the URBEMIS model, default values are suggested to calculate the portion of internal trips relative to the ITE trip generation rates, as shown in Table 5.5.

Table 5.5 Portion of Internal Trips in Mixed Use Projects, from URBEMIS

Trip Type	Isolated Development	Minor Component of Urban Area	Major Component of Urban Area
Residential Trips			
Home-Work	100%	10%	30%
Home-Shop	100%	20%	50%
Home-Other	100%	20%	50%
Non-Residential Trips			
Work	100%	10%	30%
Non-Work	100%	20%	50%

These values suggest that if the mixed use project is a major component of an urban area, up to half of the trips from home to shopping will be internal to the site. If the mixed use project is only a minor component of the metropolitan area, up to 20% of home to shopping trips will be internal. The model then uses the following formula to calculate the total trips generated by the site:

$$\textit{Net Trips} = \textit{Gross Total Trips} - (0.5 \times \textit{Gross Internal Trips})$$

While these values may not be appropriate for every mixed use project, they suggest the range of trip reduction that can be achieved. A traffic impact analysis of a mixed use project that does not account for at least some internal trips is probably overestimating the traffic impact.

Accounting for Design Factors

The URBEMIS model also allows the user to account for various "environmental factors" that can affect trips made by walking, bicycle or transit. As described earlier, the ITE trip generation rates are developed largely from studies at sites where non-auto travel is very limited. When projects are built with better urban design and transit access, some automobile trips will be diverted to other modes. URBEMIS can estimate this diversion.

Three categories of environmental factors can be used in the model: pedestrian, bicycle and transit. The user is first asked to input factors to describe the environment surrounding a project. The user gives a score to each factor within the given range, and the impact of each factor on vehicle use is calculated by the model. A listing of the factors suggests the types of design features that can affect non-automobile travel. For example, the factors used to rate the pedestrian environment are the following:

- Mixture of uses to attract pedestrians within walking distance;
- Sidewalks and pedestrian paths;
- Pedestrian circulation provides direct access;
- Street trees provide shade canopy;
- Street system designed to enhance pedestrian safety;
- Pedestrian routes provide safety from crime;
- Walking routes to important destinations provide visual interest.

Similarly, the bicycling environment is rated using the following factors:

- Area served by interconnected bikeways;
- Bike routes provide wide paved shoulders and few curb cuts;
- Speed limits of 30 MPH or less on streets with bike routes;
- Schools with safe routes;
- Mixture of uses to attract bicyclists within easy cycling distance;
- Community has bicycle parking ordinance.

The transit environment is rated using a series of formulas that account for the type of transit service (light rail, bus, etc.), the distance to the transit stop (must be within ¼ mile for bus), and the pedestrian environment around the transit station.

Once the environment around the project has been quantified, the user can then input specific mitigation measures associated with the project under study. The model estimates trip generation and emissions, reducing the default ITE rates based on some of the empirical studies discussed earlier in this chapter. The environment surrounding a project affects the amount of vehicle trip reduction. For example, a mixed use development with good pedestrian and bicycle infrastructure will produce less trip reduction when built in a low density, isolated suburban edge site compared to a higher density, urban infill site. The URBEMIS model accounts for this by using the environmental factors described above.

5.1.8 The Smart Growth INDEX Model

Another computer tool that can be used to estimate the benefits of livable communities is the Smart Growth INDEX model. Smart Growth INDEX is a sketch model for simulating alternative land-use and transportation scenarios and evaluating their outcomes using indicators of environmental performance. It is being developed by Criterion consultants for the U.S. Environmental Protection Agency. The model can be used to simulate alternatives for both large areas (like a region or sub-division) and smaller areas (like a neighborhood or single parcel). Users must create GIS maps of the study area, including layers for housing, employment, land uses, street network and transit lines. The model produces measures of land use impacts, such as residential and employment density, land use mixing, jobs/housing balance, and accessibility. It also estimates transportation, environmental and energy impacts. For example, the model can estimate the vehicle miles traveled per person per day, air pollutant emissions, or residential energy use. These impacts are calculated internally by the model using some of the land use and transportation relationships discussed earlier in this chapter.

A similar version of this model was recently used to evaluate the impact of building on an urban infill site versus a greenfield site on the urban edge (Apogee Research and Criterion, 1998). The study used the INDEX model to simulate a hypothetical development in three different case studies. Each case study consisted of modeling a large development as if it were located on an actual infill site, and then modeling the same development as if it were on an actual greenfield site. The development size remains the same in both locations, but the density and street patterns are consistent with the surrounding urban form. All three case studies show that locating the development on the infill site results in lower vehicle use and lower emissions. VMT per capita at the infill sites was roughly half that at the greenfield sites. Smog-causing emissions were 27% to 42% lower at the infill sites.

Because the Smart Growth INDEX model requires the development of GIS maps for the study area, it is probably not appropriate for individual small projects. For larger projects, the model can provide a useful tool for evaluating the impact of alternative land use and urban design scenarios, and for demonstrating the transportation and environmental benefits of livable communities.

5.2 Environmental Benefits

This section discusses two major environmental benefits of livable communities – an improvement to air quality and a reduction in the urban heat island effect.

5.2.1 Air Quality Benefits

Livable communities can lower pollutant emissions by reducing automobile use. The Los Angeles metropolitan area has the second worst air pollution in the nation. While significant improvements have been made over the past 20 years, the region continues to experience days when air pollution levels exceed human health standards.

In Southern California, the most significant air pollution problems are due to the formation of ground-level ozone, often called smog. Ozone forms in the atmosphere when volatile organic compounds (VOCs) and oxides of nitrogen (NOx) react in the presence of sunlight. The problems are most acute in the summer months. Ozone can lead to respiratory ailments and other health problems, particularly among children and the elderly.

Automobiles are the single largest source of ozone-causing emissions. Automobiles emit a large burst of pollutants when started, then continue to emit pollutants at a lower rate while being driven and while cooling down after being shut off. Because of this, reducing automobile emissions in urban areas depends heavily on reducing the starting of cars (the number of trips), not just the distance of driving (length of trips).

The greatest air quality benefits of livable communities occur when automobile trips are replaced with other travel modes, particularly non-motorized modes like walking and bicycling. The transportation benefits described in the first part of this chapter can serve as a rough estimate of the air quality benefits of livable communities. More precise estimates of air quality benefits are often difficult to make, because emission levels also depend on factors like vehicle speed, age and size. In general, increasing walking and bicycling trips are particularly beneficial because they tend to displace shorter automobile trips. Because of the high emissions that occur upon starting a vehicle, short auto trips are responsible for much greater emissions per mile than longer trips.

The National Bicycling and Walking Study sponsored by the Federal Highway Administration (FHWA, 1993) attempted to estimate emissions reductions resulting from increased pedestrian and bicycling activity. The study estimates that in 1991, bicycling and walking together displaced 0.3% to 1.2% of all NOx emissions and 0.7% to 2.6% of all VOC emissions. These fractions will rise as the share of pedestrian and bicycling trips increases. The study estimates that investment in pedestrian and bicycle infrastructure and programs can increase bicycling 3 to 5 times, and walking 1.5 to 2.5 times. If these increases occur over ten years, bicycling and walking together could displace 0.5% to 3.6% of NOx and 1.1% to 7.5% of VOC emissions.

The URBEMIS model described earlier can be used to estimate the emissions benefits of livable communities strategies. However, it is important to keep in mind that transportation and air quality benefits accrue cumulatively over time. The air quality benefits of a single project will probably be quite small, particularly if it is surrounded by land uses that do not encourage travel by alternative modes. It may be only after multiple projects are built that a neighborhood truly begins to encourage significant amounts of travel by alternative modes and air quality improvements become noticeable.

5.2.2 Benefits of Trees – the Urban Heat Island Effect

Urban areas are hotter than their surroundings, a phenomenon known as the "urban heat island" effect. Los Angeles, for example, is 6.0 to 8.0 degrees Fahrenheit hotter than the surrounding area. The result is an increase in the need for air conditioning and peak power, and therefore an increase in smog. Livable communities strategies, particularly the planting of trees, can reduce urban temperatures and thus save energy and improve air quality.

Impact of Urban Heat Island

There are two basic reasons why urban areas act as "heat islands." First, dark surfaces, especially buildings and streets, absorb more solar heat than natural surfaces. Second, less vegetation lowers the evaporation rates in urban areas. Los Angeles has been the laboratory for the study of the urban heat island effect since the early 1980s, particularly by Lawrence Berkeley Laboratory (LBL) and TreePeople, a Los Angeles-area environmental group. They have found that in 1880, the maximum annual temperature in downtown Los Angeles was 101° F. In 1934, when the amount of irrigated orchards in Los Angeles was at its peak, the high temperature was 97° F. Since then, Los Angeles has warmed steadily as buildings and pavement increased. High temperatures in the 1990s have exceeded 105° F (LBL Heat Island Group).

On warm afternoons, the demand for electricity rises nearly 2% for every degree Fahrenheit in maximum temperature, and the amount of peak power use rises 3% for every 0.5° F in daily maximum temperature. Peak power is electricity produced during the period of highest demand, and is the most expensive and typically the most polluting source of electricity. Los Angeles spends $500,000 per hour for cooling on a hot summer afternoon (in 1992 dollars). Twenty percent of this amount, or $100,000 per hour, is estimated to be caused by the urban heat island effect, for a total of approximately $100 million per year in increased electricity cost (Akbari et al., undated). This calculation was made before the deregulation of the electric utility industry, which has resulted in the rapid rise of peak electricity prices in many areas.

The higher demand for electricity at midday increases the level of pollution because more smog is formed as temperatures rise. Below 70° F, Los Angeles has a concentration of smog (ozone) below the national average. Above 95° F, every day is smoggy.

Benefits of Trees

Both LBL and TreePeople have constructed computer models to examine the impacts of reducing Los Angeles' urban heat island. According to LBL, two-fifths of the Los Angeles basin is covered by buildings and roads. These areas could be made 30% more reflective with lighter surfaces and shading by trees. If this were done, summer temperatures at 3 p.m. on August 27 could be 5.0° to 9.0° F lower, Los Angeles would consume 0.5 to 1.0 gigawatt less peak power, and ozone would be reduced 10% to 20%. This is equivalent to removing three to five million cars from the roads (Sacramento Municipal Utility District). Reducing the demand for peak power can also minimize the need to build power plants that may only be used infrequently to meet this seasonal need.

The benefits are also dramatic for individual buildings. Shade trees can make a difference in attic temperatures of 10° to 40° F on a hot day (Sacramento Municipal Utility District). One LBL study showed that, based on weather at Los Angeles International Airport, a 10% increase in shading for a typical residence can decrease the cooling load by 66%, and a 35% increase in shading can decrease cooling by 85% (Akbari et al., 1987). The LAX weather approximates the weather in much of the South Bay.

Shade trees block sunlight from roofs and walls and create a light breeze as hot air is drawn up through their branches. Plants can also be used to control wind. In Los Angeles, it is best to plant trees that branch eight to ten feet above the ground; lower branching trees – or other plants – may block prevailing onshore breezes. It is also advisable to plant deciduous rather than evergreen trees so that the winter sun can warm a building.

In addition to shading, plants secrete or "transpire" water through pores in their leaves, a process known as evapotranspiration. This water draws heat as it evaporates, cooling the air. A single mature, healthy tree with a 30-foot crown can evapotranspire up to 40 gallons of water per day, reducing home cooling costs from 10% to 30% (LBL Heat Island Group).

The temperature of an area may be reduced by plants even if they are not tall enough to give shade. Plants and grassy covers reduce temperatures by scattering light and radiation and thereby reducing the absorption of solar radiation. Temperatures over grassy surfaces on sunny summer days are about 10° to 14° F cooler than those of exposed soil. Other strategies to reduce urban heating include making roofs light in color, thereby increasing their "albedo" or reflectivity, increasing the number of fountains and pools, and spraying water on building tops.

One argument sometimes heard against planting trees is that they emit VOCs. In fact, these VOC emissions are more than offset by the reduction in NOx and VOC emissions from in-basin power plants. This results in a net benefit five to ten times greater than any cost of emissions from trees (Rosenfeld, 1988).

The TREES Model

The TreePeople have developed a cost-benefit analysis and computer model called T.R.E.E.S. (Transagency Resources for Economic and Environmental Sustainability). This model, which has recently been completed and is currently being field tested, proposes a unified, systematic approach to addressing many of Los Angeles' environmental issues. The focus of the model is on redesigning Los Angeles' urban landscape to:

- Capture rainwater, thereby reducing water use, storm water runoff and the threat of floods;
- Utilize landscaping, especially trees, to minimize the urban heat island effect and energy demand;
- Eliminate greenwaste;
- Improve air and water quality;
- Create jobs.

The T.R.E.E.S. model can analyze, among many other factors, the link between trees and air quality. The model provides a great amount of detail, down to quantifying the emissions benefits of one tree per site over time, including the comparison of the impact of different species. T.R.E.E.S. allows the user, whether a public agency, developer or other interested party, to model any combination of urban forest-based best management practices (BMPs) and land uses for any size lot or section of the Los Angeles area. The available BMPs, in addition to strategic tree planting, include mulching, pavement removal, cisterns, dry wells and graywater systems. All types of land uses can be analyzed, including single and multi-family residential, commercial, industrial and public. T.R.E.E.S. quantifies the environmental and economic benefits for air quality, energy, water demand, flood control and greenwaste. The model includes over 1,400 default assumptions, any of which can be modified by the user.